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ABSTRACT

This paper describes a research-based, Web-delivered context, the Generative Virtual Classroom (GVC), in which student teachers can develop their ability to recognize, describe, analyze, and theorize learning, and it reports findings of three investigations into its use. The learning environment aims to exploit the possibilities of advanced technologies for learning to bring about improvements on a larger scale than has so far been brought about by direct intervention through teacher education. The first two studies each involved one teacher as she engaged with the GVC, and the third study focused on five undergraduate education majors. Sustained periods of learning by teacher education students and shorter intensive engagement with the GVC during practice teaching are reported. Findings of these three studies suggest that the GVC can provoke understanding and learning, and affirm the significance of taking biological approaches to educational research. Implications for research based e-learning system development and for teacher education and teacher education research are drawn. (Contains 47 references.) (SLD)

Teacher Education in the Generative Virtual Classroom: A Web-delivered Context for Developing Learning Theories

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Teacher Education in the Generative Virtual Classroom: A Web-delivered Context for Developing Learning Theories

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This paper presents a research-based, web-delivered context (the Generative Virtual Classroom or GVC) in which student teachers can develop their ability to recognise, describe, analyse and theorise learning, and reports findings of three investigations into its use. Designed in response to well-recognised concerns about narrowly conceived, anachronistic and ineffective technology-and-science education, this e-learning environment aims to exploit the possibilities of advanced technologies for learning, to bring about larger scale improvement in classroom practice than has so far been effected by direct intervention through teacher education. Sustained periods of learning by teacher education students and shorter, intensive engagement with the GVC during practice teaching are reported. Findings suggest the worth (for understanding learning and for conducting educational research) of the biological thinking underpinning the GVC itself and these research studies of it. Implications for research-based e-learning system development and for teacher education and teacher education research are drawn.

Introduction

The Generative Virtual Classroom (GVC) is an e-learning[1] system designed to help learners (principally teacher education students but also interested others, including experienced teachers and members of school communities) to develop sophisticated and educationally powerful understandings of learning (and technology-and-science learning in particular) (Schaverien, 2000). Typically, learners hold the view that technology-and-science learning occurs simply by instruction and such a view acts as an obstacle to learning to teach technology-and-science in innovative ways (see, for example, Schaverien and Cosgrove (1997a), but also analyses of the worrying gulf between research and practice in technology-and-science and related disciplines by White and Klapper (1994), Harlen (1997) and Tobias (1999)). In its sophisticated attempt to circumvent a challenging conceptual problem, the GVC is a member of a family of learning environments at an educational crossroad, where well-used educational modes of the pre-industrial and industrial ages are intersecting with those being formulated for an information age (Tiffin and Rajasingham, 1995).

The GVC consists of a pair of nested virtual classrooms for teacher education in technology-and-science: an elementary and a tertiary one. Learners can choose to view and review exemplary learning and teaching events at their leisure, as if they are witnesses to these events in a virtual elementary classroom. Supported by a browser-based platform, they can make personal notes on these events, share their views about events with others in the virtual tertiary classroom through a threaded e-mail discussion group and record ideas, in a searchable community database, about particular, salient aspects of these children's learning. In their visits to the GVC, learners can use this database both as a source of ideas about learning and to track their own development of ideas over time. As well, whenever they choose to do so, they can access pre-recorded narrative commentaries in which learning events are interpreted according to a generative view of learning. Students are encouraged to entertain these commentaries as another plausible view, examining the criteria on which they agree or disagree with this perspective; and they can access related materials on the World Wide Web.

Biological thinking underpins both the e-learning environment and the investigations of its effectiveness reported here. This biological view gains strength from recent advances in neuroscience and evolutionary epistemology that are forging a unifying explanation for knowledge and knowledge gaining (or learning). On this view, both knowledge and knowledge gaining are considered to be adaptations: they hedge the survival chances of our species. As the neo-Darwinian synthesis (Dawkins, 1986) now explains, the inheritance of genetic knowledge can be well-described in terms of selection - as the generation of variants (in this case, genes) and the testing of these variants on their value, keeping those that survive the tests. Similarly, on this view, knowledge gaining within individuals during lifetimes (such as in immune systems and brains) (Edelman, 1992, 1993) and in the culture at large (Popper, 1968), can be characterised as selectionist phenomena as well (Plotkin, 1994, 1997): as cycles of generating ideas and testing them on their value, keeping those that survive the tests. A biologically based, generative theory of learning has been developed (Schaverien and Cosgrove, 1999); and key antecedents of this view in the literature of the learning sciences identified, including the worth of viewing learning as a generative act (after Minsky, 1985, and Wittrock, 1974, 1994). As well, the view itself has been

[1] In the few months since I submitted my proposal for this paper, the term e-learning has become commonplace. Though others confine it to purely web-based technologies, I use it here in its broadest sense: as an electronically mediated context for learning.

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subjected to detailed scrutiny for its implications for technology-and-science education in particular (Schaverien and Cosgrove, 2000). The set of studies of learning reported here is the most recent in a sustained research program conducted and interpreted in this paradigm (see, for example, Cosgrove, 1995; Cosgrove and Schaverien, 1994, 1996; Schaverien and Cosgrove, 1995, 1997a; Hall and Schaverien, 2001). The Generative Virtual Classroom is one of the latest in a family of e-learning environments designed on these educational principles (Cosgrove and Alexander, 1995; Schaverien and Cosgrove, 1997b; Schaverien, 2000; Cosgrove, Schaverien, Forret and Trowsdale, 2000).

Such biological thinking about learning is explicit and available to student teachers in the GVC itself. They can access it directly, considering its power to make sense of the learning they see in the virtual elementary classroom, and comparing and contrasting its worth with their existing views of learning and those of fellow students in the environment's virtual tertiary classroom. As well, they can examine, reflexively, the nature of their own learning in the virtual tertiary classroom and the value of describing their learning in these terms, accepting or rejecting such a view, for its fruitfulness for them over time.

As well, such biological thinking pervades the research investigations of student teachers' learning in the GVC reported here. Three (of many) indications of such a perspective illustrate this point. First, the GVC situates student teachers in a context in which they can learn whilst others (children and fellow students) learn around them. The mirroring that this makes possible is recognised to be a powerful feature in many contexts, for example, in children's early learning of their mother tongue, learning societies such as Papert's (1980) Mathland and samba school and Lave and Wenger's (1991) communities of practice. In such circumstances, I was able to test the worth of thinking about learning as adaptive: as driven by students' selection of ideas for their personal and cultural worth. Secondly, the GVC and the research investigations of which it is a part supply a particular language in which ideas about learning can be discussed. That affordance addresses a major obstacle to developing thinking about learning: the lack of words with which to talk about it. In 1980, Papert bemoaned this gap, coining the word mathetics to denote the study of learning and in 1993, he criticised language such as "The teacher teaches the child" for the passivity with which learners are so inaccurately cast. Without appropriate words encountered in everyday contexts, learners cannot easily think about ideas or talk about them with their friends (Minsky, 1994). In these studies, I was able to test the potency of a biological view of learning to supply ways of thinking about learning. Thirdly, as Minsky (1994) pointed out with respect to mathematical thinking, knowledge about learning and hence teaching is often presented in teacher education, culture and the media, as settled knowledge, as if there is no new knowledge to be created. On the contrary, advances in neuroscience, including neuropsychology, and in materialist philosophy would suggest that the field of learning is an active frontier. The GVC aims to engage student teachers at this frontier, with what Latour (1987) called science-in-the-making: these investigations assume an evolutionary perspective on knowledge generation.

The GVC and the investigations of its worth reported here engage principally with teacher education students' conceptual flexibility with respect to their thinking about learning. In doing so, they intersect with literatures on teacher thinking, school reform and classroom innovation. As well, these investigations provide important opportunities to test the generative learning theory itself, making theory advancement a key perspective of this work.

Three research studies: Designs and methodology

In addition to formative trials of components of the Generative Virtual Classroom (which will not be reported here), the development of this first browser-based version has proceeded in parallel with three research studies using both current and earlier versions. First, an experienced early educator became a participating member of the project team, and chronicled the development of her ideas about learning as the project proceeded (Sen, 1999). Secondly, a teacher education student, a member of the target population, undertook an autobiographical study of her ideas about learning over an eight-month period in the GVC (Allard, 1998). Thirdly, a group of teacher education students on practicum in schools became students in the GVC for an intensive three-week period. Their developing views of learning were tracked through their contributions to the GVC and through connections they made with it in their day-to-day practice teaching.

In all three studies, naturalistic case study methods were used to research learning in the GVC. Such approaches drew on learners' contributions to this environment over time (in the GVC's accumulating community database and e-mails to other students), diaries or other student records (including teaching-related plans and resources where appropriate), conversations between students and the researcher at salient points and observations of

students' teaching where possible. These modes of inquiry tracked the evolution of students' ideas about learning (if it occurred), detailing how such evolution might occur and the diversity that is possible in development. They were in tune with key features of biological thinking (for example, the significance of historical narrative, the understanding of development as epigenesis and the recognition of individual variation). Such features Mayr (2000) has identified as seminal Darwinian influences on modern thought and they underpin the design of the GVC itself.

Findings of the first two studies

I now summarise what occurred in the first two studies before turning my attention to reporting, in detail, the design, methodology and results of the third study.

Study 1: An early educator tracks her learning as a member of the GVC project development team

Explicit investigation of the Generative Virtual Classroom, within the terms of the learning theory on which it was to be based, began immediately its project development team was formed. An early educator and research student (Swati) joined the team, as a participating member and as a member of the target learner population, with a view to writing a case study of the project's development. However, it soon became clear that Swati's account (Sen, 1999) was beginning to centre on the sense she was making of her own learning journey as the Generative Virtual Classroom came into being. She tracked the development of her views of learning from a noticeable tentativeness (evident, to her, in her desire to align what she saw of learning with others' descriptions or categorisations of it) to an increasing ability to describe learning for herself, in her own terms, and to recognise it when it occurred. She began to make sense of the children's learning in those digitised video excerpts that would form the core of the Generative Virtual Classroom; and she drew on what she saw of the learning of other members of the project team. Interestingly, Swati notes that she was slowest to focus on and identify the characteristics of her own learning within the project team. However, when this occurred, she felt she had evolved a fully integrated and educationally powerful view of learning, one that supplied her with words to describe learning and criteria by which to recognise it. So, even before the distinctive amalgam of the Classroom came to be, Swati's autobiographical case study affirmed the effectiveness, in deepening her view of learning, of her participation in the project team. As well, the events in her account appeared to be consistent with and well explained by the particular (generative) theory of learning being designed in to this learning environment.

Of course, this student's experience of participating in the project development team, though similar in some respects to that of a learner in the fully developed environment, also differed markedly from it. Thorough-going, larger-scale testing of this environment's capacity to respond to the diversity of learners' needs and interests was dependent on solving several technical problems; and development of a robust version of the GVC, one which could be reliably delivered any time, anywhere, was to be another year off. Meanwhile, so as not to lose even more research time, a robust enough Version 2 was subjected to a sustained research investigation.

Study 2: A teacher education (Honours) student engages with the GVC

A teacher education (Honours) student (Megan) undertook an eight-month case study of what happened to her views of learning as she worked in Version 2 of the Generative Virtual Classroom (Allard, 1998). Unfortunately, this investigation was necessarily constrained: due to the afore-mentioned technical difficulties, Megan did not become a part of a virtual learning community but worked alone in the GVC throughout her study. Nevertheless, she was able to become a part of two similarly focused face-to-face learning communities (within her Honours Computer-mediated learning class and by attending a staff development day at a local school where teachers were working in the GVC).

In documenting the development of her thinking, Megan discerned three phases. The first phase (of just over two months' duration) was spent in detailed but comparatively superficial and tentative exploration of the video excerpts. While she made detailed journal records, Megan did not feel confident enough to enter any of her views in the community database. Nor did she feel that she could make any sense of the commentaries provided about these learning events. However, this initial phase provoked in her an urgent desire to pursue her own curiosity about learning. This she did in a second phase (of four months' duration). This second phase was marked by a period of six weeks in which she did not visit the GVC at all. Instead, Megan pursued her own ideas about learning, thinking and brain function, away from it. She noticeably gained in confidence in

recording her thoughts and feelings, drawing on her everyday life experiences to test her ideas. By the end of this second phase, Megan felt drawn to return to the GVC in a final phase (of just over one month's duration). Her account of her thinking during this third phase provides evidence that she had formed a deeper, subtler appreciation of the learning events depicted in the GVC and that she was able to articulate her thinking about them more clearly than in the initial period of her study. She appeared to be able to bring to bear her own insights (from the second phase of her study) so as to make more profound sense of the children's learning. Furthermore, choosing to analyse her own learning under the very same headings she had used to explore the children's learning in the GVC's community database, Megan demonstrated that she recognised certain similarities between the children's and her own learning there. Summarising detailed evidence, Megan claimed the GVC had allowed her to describe learning accurately and boldly. Now able to move her thoughts about learning around, in words, she could identify significant changes in her knowledge state over the course of her investigation, just as Sen (1999) could. In particular, she could discern the limits of her understanding of learning. In precisely the same terms in which one of the children in the elementary virtual classroom (Daniel) had crystallised his knowledge and his ignorance of electricity, Megan concluded,

> Whilst by the end of my study I could describe and identify learning when it occurred, there were still things I wanted to know about it. Recognising that I am still unsure of what happens inside the brain when a person learns, a more critical question for me now would be, 'What is learning in itself?'(Allard, 1998, p. 109)

Megan's most enduring idea was the development of an urgent and, in some ways, even childlike fascination with the very basis of teaching: learning. Ironically, this fascination, though central to the professional practice of teaching, had not been provoked before in her four-year teacher education degree.

These two early research investigations prepared the ground for a third, larger study in which teacher education students on practicum became learners in the web-delivered GVC over an intensive three-week period.

Study 3: Teacher education students' learning in the GVC during practice teaching

Essentially, this third study investigated teacher education students' learning to teach in a complex, hybrid e-learning environment in schools during a scheduled teaching practicum.

Design and methodology of this study

Five undergraduate teacher education students (three female and two male) agreed to participate in the study. These students were undertaking a three-week teaching practicum as a routine part of their Third Year undergraduate elementary teacher education degree. This practicum, the sixth teaching practicum of their course, required students to complete their own detailed studies of three focuses of interest within their placement school. In order to conduct this research, Department of Education and Training permission was sought and gained to place an e-learning system, the GVC, at two suburban north shore Sydney schools for the use of these teacher education students on practicum and to observe these students and their classes on two occasions during the practicum period. Permission was also sought and gained to conduct this study from the University's Human Research Ethics Committee.

On a visit to the two schools on the first day of practicum, I informed the five teacher education students placed at these two schools (two female and two male students at School 1 (Prue, Jill, Tony and Clive) and one female student (Tina) at School 2) that, if they chose to participate, the research project would investigate their learning to teach in this hybrid e-learning environment. During the practicum period, they would be required to spend the equivalent of one lesson learning in the GVC each day. I would observe each participating teacher education student teach two lessons in their classrooms during the practicum and tape-record a conversation about each of these lessons afterwards with each student. Such conversation would range broadly over the students' purposes, planning and evaluation of their lessons and would include any ideas related to the GVC that the student chose to make explicit. At the end of the three-week practicum period, when the students returned to campus, participating students would take part in a tape-recorded group conversation about their experience. I explained to the students that the research project would be unconnected with the assessment of their practicum (though, with their agreement, I would like to attend the students' presentations, to their tertiary practicum advisor, of their three focuses of interest). The five students were offered the choice of participating in the research project and all five agreed to do so.

As agreed, I visited the schools twice over the three-week practicum period, observing two lessons taught by each student (except for the student at School 2 where I was only able to observe one lesson, although I talked with this student about her second lesson immediately afterwards). I took written fieldnotes as aides-memoires of what occurred in the lessons and I noted any connections I suspected the students to be making with the Generative Virtual Classroom as I watched. I taped individual conversations with each student after each lesson for later transcription and all five students participated in a group conversation about the experience on their return to University after the practicum. I attended the five students' presentations to their tertiary advisor on campus after the practicum and took fieldnotes of what they said. Occasionally, over the three-week period of practicum, I contributed to the email discussion in the GVC, as did Megan, the former Honours student (now a teacher) who had spent eight months in the GVC in the second study described above.

Some findings of this study

I report the findings of this study in two sections. First, I describe events relating to the learning of two of the five participating teacher education students over the course of the three-week period of the research, before situating these stories, where possible and appropriate, with reference to the other students' learning and in the context of the group's discussion, on campus, after the practicum had ended. Then, I analyse these findings in tune with the biological perspectives that inform both the GVC and the investigations themselves, before attempting to draw some pertinent educational and scientific implications from all three reported studies.

Despite efforts to ensure the stability of the e-learning systems through visits to both schools prior to the arrival of the students on practicum, technical problems occurred throughout the first week of the study. The Department of Education and Training server failed on two days and an oversight in circumventing server security systems at one school limited students' access in the crucial first days of the study. However, thanks to the flexibility of one of the school principals (in allowing students to go home early and access the GVC from home), little research time was lost.

By the time of my first visit to the two schools, midway through the second week of the project, all major technical problems had been solved and students had settled into visiting the GVC either at home or at school or both, according to their own individual schedules, undertaking a variety of activities focused on the GVC's learning events.

Prue's Story

Prue's first contribution to the GVC's email discussion revealed her immediate concern with making sense of what she was seeing in the virtual classroom by comparing it to real classrooms. Having perceived Scott's actions in the event titled *Scott and batteries* as not entirely natural, she wanted to know whether I, as the teacher-researcher in the excerpt, saw it this way, too, and if so, how I dealt with that. She addressed her email to me,

> Lyn, I have just watched the Scott batteries video and noticed that Scott seemed very aware of the camera (or your presence?). I was wondering how you acknowledge this in your research? Do you do anything to try and get "natural" responses from the children? Does it matter? Do you find this setting different from what can be achieved in a classroom? So far, I have found myself thinking about ways what I have seen may be adapted to my teaching (which I am happy about) and wondered if you or any other contributors would like to discuss this? :) (23/10)

I replied, noting that other researchers have also noticed children's awareness of the camera and their becoming, in Goldman Segall's (1991) view, more full of the stuff of life, as a result of it. As to whether this is unnatural, I wrote,

> I have thought about this a lot when I watch these videos. I am not sure that they are "unnatural" because of this, though. Rather in Scott's case, his explanations appear to me to be all the more vivid or graphic - he acts them for us. I think that other children in this set of events drift in and out of an awareness of the video, at times seeming to forget that it is there altogether. I am not sure that the video is really all that much different from the personas that children (and teachers) adopt in the sometimes very public space of a classroom anyway, but this is something others might want to discuss. (23/10)

Though these were starting points for Prue's early consideration of events in the virtual classroom (and they have been important for other learners, too, for example, Sen (1999)), there was little further discussion of these ideas within the learning community of the present project.

Two days later, I visited the school and watched as Prue gave a lesson on capacity to her Year 2 practicum class. She talked with the children first to explain, through teacher-guided question and answer, how she wanted them to measure the capacity of a range of containers, using water, sand and cups and how she wanted them to record their results. Then she set the children to work in small groups outside the classroom. There was much enthusiastic conversation in the groups as the children measured. I overheard one small boy say to his friend, "I think Miss H should be a teacher right now."

When I enquired as to why he thought Prue was ready to be a teacher, he said, "Because she isn't bossy, she teaches us a lot, she knows a lot about Maths and she makes it fun."

Once the children had finished their activity, Prue gathered them together on the floor at the front of the classroom to discuss their findings. Amongst many comments the children made were the following two, relating directly to issues Prue raised with me in conversation after the lesson:

- One group of children had invented their own measuring strategy by making explicit the relationships between the capacities of the three different measuring cups they were using. This allowed them to streamline the measuring process in their group. Prue had noticed the strategy as it was being developed and invited them to describe it to the class in the concluding discussion. They told the other children, "We found that one little cup equals one medium cup and two medium cups make one green cup," and then proceeded to explain how many of each cup each container held.
- One boy (Matthew) commented, "Water is one of the *easiest* things to measure with because it has no air gaps but sometimes it goes over the top."

After the lesson Prue began the conversation with me by commenting that she did not have a particularly strong science background and that therefore she "can't look at [a learning event in the GVC] and see the science in it." In fact, she admitted that she would really like to be able to do so and hoped that by spending time in the GVC she might be able to improve her capacity to do this. Even at this early stage, Prue had already identified what she needed and wanted to learn from her GVC experience. Furthermore, the conversation was to reveal that she had not only diagnosed her own difficulties in this regard, but she was already at work, using the GVC, to sort out for herself how she might have got to be this way,

> The thing is I do very well at science at uni which is what surprises me, but to then go and watch this and go, "I don't understand what he's learning." It's not that I don't understand what he's learning, it's that I watch it and then I think, like I don't .... To see something and say, what did he learn about? – conservation and transfer of whatever. They're not even things that I think about, like I don't understand [those] concepts. And then a bit later, something was said, someone I think in the community views or in a discussion board said, somewhere, ... your early learning experiences are very important because then when you build on them, you need to, like if there's gaps and you try to then build on something that has gaps in it, that's not so good. And, um, (quite softly and slowly) I think maybe that's me because if I had these strong understandings about science I'd be able to pick up on [science ideas] more quickly. And I think that's actually, just thinking now, that's actually important for when I do teach. I have to learn things from scratch, I think, because, like, so many things I don't actually know what I'm doing, if that makes sense. I don't know the actual content, and I think if I don't know the content to teach them, they're going to miss out on it as well, because I won't be guiding. I won't know if they come up with something, I won't know if it's something that they should be coming up with or what.

Prue could also recognise her own strengths as a learner and a teacher. She commented to me that although she felt she was not easily able to perceive the science ideas in the GVC, she was able to pick up on issues relating to teaching generally. Already she was perceiving "the importance of conversation between children for their learning,"

> The importance of conversation and discussion and sharing their ideas and having someone listen to them when they say what they think is happening, and things like that, and getting it out and talking about it, rather than sitting there and thinking, and I know that this is the case with myself, rather than sitting there and thinking about something and going, "Yeah, I know that." I think that when you talk

about it and get it out then it clarifies things in your mind a bit more. So, that's why I chose the Maths 'cause I thought that that would be my principle of GVC there where they're talking and discussing as they're working.

I felt that I could corroborate, from what I saw of Prue's teaching that day and her conversation about it afterwards, both her doubts about her ability to perceive the science in children's learning and her primary focus on teaching strategies. In her concluding conversation with the children in her classroom, even though Prue sensed the importance of Matthew's comment about water, I felt that she had missed an opportunity to exploit its philosophical edge. For me, as I explained to Prue in conversation, Matthew's comment – in particular, his dallying over, his delight in and his expression of the ease with which one could measure capacity with water – signalled this young child's clear appreciation of the essential nature of a fluid. He just about giggled as he raised the problem that it was almost *too* easy to measure capacity with water, because water overflowed a container. This early, rich appreciation of the essential nature of fluids could have provided opportunities to explore other fluids for their similarities to and differences from water – and to move on towards ordering fluids according to their viscosity or to thinking about what might cause substances to behave in these characteristic ways.

Similarly, though Prue sensed the importance of the measuring strategy that the group of boys devised, she did not exploit its mathematical or its technological significance. Such a strategy relied for its effectiveness on the mathematical relationship between the cups, a relationship the boys appreciated and exploited and one that Prue might have helped them to express as an algebraic formula. Such expression could have helped the children to appreciate that their strategy worked because of a mathematical truth; and it would have given them a translation (into the language of algebra) for what they had so clearly expressed in words. Implicit in their use of this strategy was their appreciation that it had clear technological advantages for their group, in that it allowed the task to proceed more quickly. All members of the group could work simultaneously once the relationship between their different cups had been understood. In effect, they had constructed a more optimal solution pathway, albeit one with different costs and benefits. Prue might have probed for these, by asking the children on what bases they thought their strategy constituted an improvement and whether there might have been other solution pathways that they did not consider. I am not arguing that Prue ought to have taken exactly these teaching pathways and it is far easier to suggest what might have been done after the event than to exploit opportunities as they occur. Nevertheless, I concurred with Prue that there were opportunities to develop important scientific and technological ideas in this lesson which she sensed but did not know how to pursue. As she admitted,

> Like, I don't tell this to my teachers. Why point out your faults? But my worst thing is when children come up with answers and things, like, going on with what they bring up. Like, I'm all right with my plan, with what I'm saying. Let's keep to my plan. Then when they come up - I don't think I do it incredibly badly because someone would have pointed it out to me otherwise, like in three years so far. But that's the thing I'd like to be *really* good at is, when they say something ...[I can] say something that's like, doesn't just pass them off, that they actually feel like I've said something that's worthwhile back to them or helped them, or you know, or acknowledged their point of view as being good as opposed to just "OK, that's good, shut up." You know what I mean? So, you've hit on my thing that is my worst, my biggest worry, and today it was just a shocker.

The lesson itself and this conversation with Prue immediately afterwards also corroborated the confidence she felt in her ability to pick up on issues related to teaching generally. Clearly a competent and professional Education student with respect to conventional classroom management, Prue confided to me that she had been very unhappy with her performance in this regard during this lesson. In fact, Prue admitted that it wasn't until the very end of the lesson (after I had left the classroom) that she had felt her orchestration of the discussion improve, a judgement affirmed by the classroom teacher. She described the solution she had reached in these words,

> At the end of that Maths ... I really started to fire with my questions like that. ... because I was asking questions ... and it was the fact that I wanted them to all, because some of them were going off a bit, so I started asking questions, but it was. It was the quality of questions that they wanted. At first they didn't care, then they wanted to answer my questions, they were interested in what I was saying. If I had to think about what it was that changed, what was it? I can remember the looks on their faces and putting their hands up, but I can't remember what they were saying though. They were talking about, they were

ordering things in the order and which was heaviest and stuff. I think it's 'cause I started with questions that were facts, like "What was Sonny's weight?" (Sonny's that thing on the floor.) And from there, "So is he heaviest or lightest?" so then they knew, they knew something so that when they had to take a guess or make a comment about it, they knew that they were using that answer to make their guess. Rather than saying, "What was the heaviest thing?" I said instead, "What was Sonny's weight? So was he heavier or lighter?" So then they knew.

So, having pressed herself to try to articulate what constituted this improvement in the quality of her questions, she concluded that she had regained most children's attention by forming up a questioning sequence composed of tiny, progressive steps. Once a child had answered one question, the children had a clue to the answer to the next one and so on. I took the opportunity of being the Devil's Advocate and asked,

> As far as the criteria for judging that that was OK, I mean if you're taking a management perspective, then it was controlled, if you like, whereas what you said before, was the fear that it would be somehow uncontrolled. But what if, if people vary in what they find interesting and what they find significant and what they learn out of something, then might it not be that the more uncontrolled it is, the greater the potential for learning?

Prue was quick to express her understanding of my point, relating it immediately to her experience of the lesson.

> Yes, but ... when we went outside, I was ready for disaster. I thought, "Oh my God, they're fighting over the water, and they're doing this and they're doing that!" Like, it just looked like a rabble to me, because I wanted them to be nice and ordered and, you know what I mean, and not get in trouble. You know what I mean? I didn't want my teacher to look at me and go, "They're out of control." Because I would have thought, OK, here's an insight. I would have thought if they're out of control, they're not learning anything because they're fighting over the water or they're doing this or that. When I calmed down and got them out of the way of the water and I looked at what they were doing, a lot of them were actually really into it. And maybe they were fighting over the water because they wanted to get to the water and do their measurement. And so, but, [it was] very hard to let go and stand back and let them have, you know, do it for themselves. I did learn a lot then because that was what it was!

In our conversation, on this day, Prue resolved the dilemma in familiar, conventional terms: as a question of achieving a balance between teacher control and learner freedom, a balance that could support learning as well. She did not make any explicit connections between these issues and learning events in the GVC at this point.

Subsequent to these events, although Prue spent much time in the Generative Virtual Classroom and seemed to enjoy the experience of reflecting on events there and in her classroom teaching, she did not contribute a great many written comments, either to the community database or to the email discussion. She seemed to prefer talking about her GVC-related ideas. In fact, she noted in her presentation to her tertiary supervisor after the end of the practicum how much she had enjoyed and benefited from the collegiality that had developed amongst the four students,

> This practicum has been unlike any other, the key thing being the opportunity it provided for us to be collegial. The opportunities we had to talk felt enjoyable but legitimate. I felt like I was doing my job. [It was in large part due to] the structure with the GVC. There was a half an hour between the end of lunch and the start of our GVC hour (from 2 to 3pm). We would sit and talk about teaching. .... We could have just chatted but we didn't and we really liked this. As part of this prac, we had to look at how we each taught, but the conversations we had [during this half hour] were far more valuable. That illustrates the value of the whole. ...Our talking became relaxed and it was easy to watch each others' lessons and to collaborate. It flowed well and it was good fun.

Perhaps there was little extra value for Prue in writing her ideas down in the GVC environment in these circumstances, even though its presence appeared serendipitously to have played an important part in the successful emergence of these students' learning community. Significantly, when she summarised her work in the GVC for her tertiary advisor in her presentation, Prue said,

> I couldn't look at the actual science. I talked with Lyn about that. I couldn't do that *at all*. What I did do was pick up on teaching approach, trying questioning, pair work, conversation ... [I worked on] control –

> learning to let go, [realising] that the learning is more important ... and the control is there to facilitate learning.

In the circumstances in which she found herself on this practicum, Prue had managed to articulate her own clearly defined purposes. Furthermore, even in this short space of time, she was quick to focus on her own learning behaviours, as if she sensed that such a focus was crucial to achieving those purposes. In fact, her conversation was peppered with references to them. As well, early in the study she had identified a crucial tension in her own teaching between teacher control and learner *freedom*; and by the end of the study, she had subtly reconfigured this relationship so that *learning* was central and teacher control was there to make the learning happen. This new milieu ought to provide more fertile ground in which to grow an understanding of how children learn science. In her references to her personal learning history and in her realisation of the make-or-break influence of teacher control on children's learning, Prue's story is reminiscent of Jan's (Schaverien and Cosgrove, 1997a). We do not know whether Prue, given extended time in this hybrid learning environment, would develop a personal strategy, as Jan did, to relinquish teaching behaviours she came to perceive as obstructing children's learning. However, we could speculate that, given extended time and opportune circumstances, Prue might well be single-minded enough to improve her ability to discern the science in children's learning, regenerating teaching strategies to support such a focus.

Tony's Story

Tony's very first contribution (20/10) to the GVC's community database concerned the learning event entitled *Scott and Batteries*. This event shows two six-year-old children, one of whom (Scott) engages in what is almost a soliloquy on the subject of batteries, in response to the other child's (Cameron's) question about a battery's lifetime. First Tony listed some key ideas he could identify from what Scott said. On reaching Scott's emotive statement about batteries exploding if they are cut in half, Tony interrupts his list to remark, "He considers this information valuable, he is warning Lyn and Cameron (?) of the dangers of acid, how it burns."

And then,

> This scene reiterates the importance of adults giving children clear answers to questions. Analogies used by Scott appear to leave him floundering for ideas. How can a liquid burn when it is not hot? He says the expired battery has water on it. This could be very confusing. Would it help to describe the nature of an acid as a liquid which contains elements that can burn his skin? How does a child differentiate between a bottle of Hydrochloric acid and a bottle of water? (20/10)

Tony's comment about Scott's valuing of an idea is barely noticeable in the terrain of his thinking in this first written piece. Yet, this idea was to become central to Tony's thinking over the course of the practicum period. Here in this first contribution, he spent barely a sentence on it before turning to think about adults' responsibilities with regard to explaining difficult ideas. As a parent, he clearly had safety concerns in mind when he pondered the difficulty for children of differentiating between water and acid. But then, the reasons for Scott's valuing of this idea still appeared to be weighing on his mind. He returned to consider what an adult might do to help this child resolve what appeared to him to be confusion. Framing his thoughts as questions is significant; so, too are the questions themselves, beginning as they do with "Would it help to describe the nature of an acid as ...?" and "How does a child differentiate between ...?" Even at this early stage, Tony seemed to be flagging, in the former question, his uncertainty about the effectiveness of transmission as a teaching approach and in the latter, his interest in the ways children might go about making sense of their world.

Four days later, Tony's interest in these two issues seemed not to have abated. He had turned his attention to a different learning event in which Alicia, a ten-year-old, was exploring batteries. Tony was focusing his thinking on the effect on Alicia's understanding of printing a use-by-date on the outside of the cell. He could see two problems. On one hand, Alicia appeared to take the information too literally, as "a definite cut off point for the usefulness of the battery" rather than as a date from which "if left unused performance of this battery will begin to reduce." On the other hand, Tony acknowledged the need for such information if learners were to be able to do a proper test of the battery function. In the light of this discussion, his own position moved from initially considering the worth of a totally unmarked battery to appearing to favour one which had some information about expiry, but in a less confusing form than a simple use-by-date. Echoing his continuing interest in the dynamic between the culture's provision of information and young learners' own sense-making capabilities, Tony concluded, "The girl has ideas about circuits, it is Duracell who has created the confusion." (24/10)

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On the same day, Tony replied to Prue's comments concerning the effects of the camera on the children in the virtual classroom. For Tony, these children's sustained engagement with their tasks was evidence that they were not distracted by the camera. Obviously, impressed by their level of engagement, he wrote,

> It appears that the girls are exploring many varied aspects of circuitry and battery function. They don't want the session to end. It has them fascinated. ... As the bulb gets brighter the interest level grows and their dialogue drops off. What do you think? Is this constructivist session helping these girls learn about electricity or what? (24/10)

The next day, I visited Tony at school. I observed him give a geometry lesson on angles to his Year 5 practicum class. Tony introduced the lesson by asking the children to think about who would use angles in the real world. Immediately the supervising teacher interjected, suggesting the children think about her daughter (who is confined to a wheelchair) and how she might get in and out of buildings. The children listed a number of purposes for knowing about angles, and were then given a worksheet on measuring angles with protractors. Tony circulated so as to monitor the children's understanding, peppering his conversation with them with ideas about the purposeful use of angles where he could.

At lunchtime, we sat down to talk and I asked Tony about any issues that were arising for him from the use of the GVC and any thinking that he was doing as he taught or watched learning events, real and virtual. He began reflectively,

> Yeah, a number of issues and at different layers. It's helping me, I think introducing the experience of working with the GVC whilst on a [school] placement has helped me to just look at the different layering of the educational process and it's reminded me of the need to, because, see in the examples that we're given we're just looking at the child's perception of an event and getting them to express their concepts and their understanding and their prior knowledge and that's made me reflect on how I've approached the lessons. So I was given a very standard, structured lesson on angles to do this morning and I realised that I could have just given that lesson and have them do the exercises on measuring angles and so on, but being reminded of what we were seeing in the GVC and of particularly the rich scenarios, I think, about the girls with the batteries, Alicia and Erin, and it made me remember that I should real-world it, like make the angles lesson keep the children thinking about how it applies, like adding value to it. 'Cause I thought, it's a pretty abstract concept. Well, it's a totally abstract concept to a child. Why should I measure an angle anyway? What's 90° to me? It's really nothing. So, and it made me really reflect on the fact that I need to try and bring it back to something that they can relate to and that's what I felt just from looking at what I'd seen on GVC so far, I thought, well, it's important to keep bringing that back into it.

The general point Tony was making about the need for real-world relevance, whilst significant, is common folk wisdom. Now that he was acknowledging a central role for the GVC in helping him appreciate this, I wanted to know, in a little more detail, how that had happened. I asked him if there had been a particular thing that had provoked that insight. For a few seconds, he searched aloud through the details he recalled of what Alicia and Erin had been doing, and then,

> I know there was an aspect of what they were discussing that made me think, well - (And then suddenly brightening and quickening his pace) Oh, that's right, about the lifespan of the batteries. I'm really hung up on that. That's the thing I've got, I've looked at the first [learning event in the GVC] with, I think it's Daniel and the batteries, and how he's talking about the acid and it burns,
>
> Lyn: Scott?
>
> Scott, right, OK, and then these two girls and they both got hung up on the expiry date of the battery. Now that, I thought was a real-world push in on that theory, because the fact that that's printed on the battery has changed their perception of what the battery does and it's given them a clue that it's an exhaustible energy source. But, if there was no indicator on that, like if that battery was, I think I put that in my dialogue, if the battery was just like blank, or painted white or whatever, there'd be nothing there to suggest to them, unless someone's told them and they've brought that in as prior knowledge, that that battery's going to be exhaustible. And then the girls are tossing up that idea of are they recharging the

batteries because they're running them in series and all that. And that's what made me think, I know it's a tenuous link,

Lyn: It's an interesting link.

But that's what made me realise that that external force, that external, it's really the only - what am I trying to say? It's the only thing in that experiment with those two girls that is an external push into that experiment 'cause the wire's just wire, the wood's just wood, but the battery's got its brand name and its details on it and that's affected their concept of the whole experiment. And that's what made me think, when I was looking at the angles with the kids, you know, I had to take what was abstract and unmarked and make it, and tag it for them in the real world, so that they could, like [I had to] add that value to it. And that's the thing that I've looked at, like, I've only looked at those two [learning events in the GVC] so far, where the kids have had, quite a bit of their discourse has been sorting through this idea that the battery's going to run out. And really the only thing that tells them that, as far as I can see, anyway, [is] that there's that expiry date on the object itself.

It had been clear from his written comment thus far that Tony had been considering, in fine-grain, the learning of the children in the virtual classroom. This first conversation with him affirmed and extended that finding: Tony was also making direct attempts to use these insights in his own teaching. He seemed to see a way of doing this, by building in the real-world relevance himself, as far as he was able as a teacher, into the design and delivery of those learning experiences for which he was responsible.

However, in the conversation that followed, it was clear this pat solution was breaking down before his eyes, worrying away at him like a grain of sand in an oyster, for there was a much more fundamental issue to raise. He began reflectively again, this time thinking aloud about the absence he was noting of what he termed constructivist teaching practice and the prevalence, instead, of "very structured and rigid" approaches.

They're not encouraging the children to *think*. ... I don't see the fruit of it when I challenge them like that. ... [It's] mind-reading sort of teaching, where the teacher has an answer and is standing there, blank, and the children have to try and guess what's in their mind. And I'm really thinking, hey, I don't really like that, I don't like that at all, because children aren't mind readers. Communication and learning is through expression. Guessing and checking is a good problem-solving process to use, but, the idea of, hey, the kids need to know what's going on. They need to have some idea of what the whole outcome of the lesson is. So, it seems to me like it's sort of ... like a magic trick. You've got to pull it out. The kids are being asked to pull out the answer whereas I think it should all be laid down and then explored, you know like we see in those science experiments [in the GVC] where, here's the material, and you come to it and just see what you can make of it and then we'll look at where you come to with it. And that's what I've sort of realised, I had that structure in that angles lesson, but I'd much rather look at angles and go, "Why are people looking at angles in the first place? Why is it important to humanity that we understand how to measure an angle? What's it done for us? What can you do with it? What can you do with it as a child?"

Now, Tony seemed to be pulling back from the fine-grained detail of the learning to examine features of the context in which this learning was taking place. His effort to inject relevance into that highly structured angles lesson had been well intentioned but less than successful, exposing a deeper flaw in the planning of the experience. Explaining the difficulty led him to describe a similar and even more pointed example of a Physical Education lesson he had given the day before. His co-operating teacher had felt that it had lacked structure, that it had been too open-ended and that it had not moved along at an appropriate pace. However, Tony had been trying to challenge the children to come up with their own ideas about movement, which took time. Talking about this difference of opinion with his co-operating teacher over this lesson prompted Tony to muse over the appropriateness in different discipline areas (Music, Physical Education and Mathematics) of taking such time to think. Perhaps it was a question of the character of the discipline, he was implicitly arguing, but the argument hardly even stood up.

See, they think that slow time is wasted time, but you can see that they're thinking. Some kids might wander off, but I could see that there was enough of them there going, "Oh, yeah. What's he on about?" And that's why I think that bringing it back to looking at how children learn and discussing it by spending some time reflecting on it during the prac has been really valuable. And we've been pushing

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really hard to assert that time on it and value it and push to get the resources to work for us. It all comes back to that value thinking, adding value to it.

Clearly, Tony was trying to plan his lessons so that the children could take on the major intellectual work and he was attempting to build in spaces for them to do it. However, as discussion of this point began to slow, his return to considering value interested me. It was as if the issue had simmered quietly all this time, underneath our conversation. I asked him, "So, that's something that you're noticing from the GVC environment, this, sort of, adding value? You're using that term a lot."

He nodded,

> I'm just starting to feel that that's an important aspect of teaching abstract ideas to children, that they can relate it to themselves in their own way, but they need to construct that. I can't construct what's valuable for them. I can perhaps say that I find this valuable or other people find this valuable, but how is it valuable to you? And some of these general laws of physics or nature that we know of, they all have an inherent value to each individual because they have to work in this three-dimensional world, many dimensional world. So, that's why I think it's important, whether it's a social value, a physical value or a career value, relationships or whatever it is.

Again I was interested in hearing, much more specifically, about the part that the GVC environment had played in shaping these ideas and prioritising them within Tony's thinking about education. Expecting him to return to examples of the children in the learning events we had discussed, I asked him, "So, how did the GVC foreground that for you?" I remember acutely my surge of surprise (and it has to be said, delight) at his response.

> Well, I just felt that because I'm being asked to put my ideas in, there is an implicit value in what my input it, so I feel that my contribution has value to the community, that it's going to create some discourse over the topics that I raise. And likewise the opinions of the other people involved in the discussion groups. So, that made me realise that my thoughts and my understandings that I'm developing as a learning teacher and a teacher learner is valuable. And that's valuable to my career, but also as a thinker and a member of this learning community. And that made me reflect on looking at some more abstract ideas for the kids and how they can value their own opinion or their own concept on the given topic whatever it is.
>
> Lyn: (very quietly) That's a really interesting connection you're making there.
>
> Mmmm. Because I think people struggle at a tertiary level to, well, some of my cohort, some of the discussions I've had over the years that I've been studying has been about that, and what's this mean? And what's the value of this and why am I doing this to become a teacher? And it's just something that has challenged me all the way along. There's been some subjects that people have been really challenged to apply to the real world. And so that's why I thought it is so important. We *are* being valued. Most people wouldn't ask us, we wouldn't be here if there wasn't a value to what we were going through as learners for the teachers as well, you know.

My studies of adult learners in this e-learning system and in other classroom environments have led me to expect (and value) the inevitable, idiosyncratic connections these learners make between their own learning and the children's. Many talk of having had similar experiences or reactions to the children (as Tina did in this study in relation to first watching a strobe light) or having asked similar questions (as Jan did about batteries in a prior study (Schaverien and Cosgrove, 1997a). However, Tony was making a new kind of connection: between his experience, as a learner, in a context in which he felt he was being given dignity, and the kind of learning environment he wanted to build for children.

What Tony was describing was central to the idea of generative learning, itself. I was keen to know Tony's perspective on a conversation Tony had had with Clive, a conversation Clive had reported to me that morning. They had discussed uncertainty about the exact meaning of generative in the title, Generative Virtual Classroom, and in the expression generative learning.

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> Yeah I was stuck on that, the definition. I'm trying to remember the conversation. Well, we are generating this virtual classroom, 'cause it's coming from nothing, except our viewing of this material. And here it comes – Whew! What are we going to learn out of this? What Clive thinks, what Prue and all of the other people involved think.

For Tony, generating meant creating. He was less certain, and expressed his puzzlement, about using the word in the context of a generative view, but he did not dwell on it. Nor did he ask directly for an explanation from me. Rather, he was interested to know if, and how, he might join in on the pre-recorded conversation (the generative view) between Megan and me in the virtual classroom. Whilst there were indirect ways that Tony could do that in the current version of the GVC (through the email discussion, for example), his question has provoked me to think about building such opportunities into the next version. Perhaps the provision of this hybrid e-learning system and its investigation had provoked the students' thinking about the worth of this context for them, for Tony continued,

> But it's been really interesting and it's made me think, just made me *think* about how *I* see it, sort of, developing my own viewpoint and analysis of what I see on the video, once we got all the bugs under control. It's been exciting. And, too, we've all talked about your, like Lyn's coming to watch us and we're going, well, what are we doing out of this that's been raised out of the GVC? And I've countered that by saying well, nothing. If you want to say nothing, that's valid. If you don't feel that it's affected you in any way, then it's important to say that.
>
> Lyn: Yes, obviously, obviously.
>
> You don't need to say that it's done anything for you. Otherwise you're making it up. ... The challenge is to make the connection. For me, that's where the challenge always lies in study, to make the connection. It reminds me of the constructivist view and I think it's really valuable to my teaching and my relationship with the class and understanding where they're all coming from so their learning can go where they need it to go not where I say it has to go. And that's where I think, looking at these experiments, the children have been exposed to the material and they've responded to it and from that a lot could come. Lessons could come for those children from that.

I reminded Tony that Tina had made this precise point on the email discussion that week. She had drawn up a long list of topics that the learning event, *Scott and Batteries*, had suggested for her; and consideration of this list launched us into a discussion of our different interpretations of how Scott viewed batteries. Tony's interpretation hinged on the view that Scott was using the word "water" to mean "liquid," an interpretation that I had not countenanced before. Our difference of opinion provoked us both to review the event and, though I have not changed my view of it, I can see how Tony generated his interpretation. The conversation ended with Tony's summary of his thinking at that point and his brief comment about the advantages of building in some stand-alone facility into the GVC to circumvent networking problems.

Later that day, Tony revisited the GVC and looked at the *Daniel and Earthquakes* event. Speculating about the origins of Daniel's curiosity and explicitly envisaging, for Daniel, a learning environment similar to the one he himself is presently enjoying, he wrote,

> What has made Daniel decide that this knowledge is important? Is he linking this with a latent fear of the danger of earthquakes? Has he seen news footage of children and families in an earthquake aftermath? Is he fascinated with the idea that something as 'solid' as the earth is moving? ... Could a generative discourse similar to this one (in the GVC), aimed at primary [elementary school] learners, help them to value their opinions and those of their peers? Could an on line discussion provide an impetus to test theories Daniel has developed? (25/10)

The next day, Tony's two contributions to the email discussion list concerned the tension between the culture's prevailing view of learning and the one he was developing. He wrote,

> Do we as educators have to re-educate the parents and community groups to value children's knowledge differently? ... In the era of basic skills tests and accountability, can we justify allowing children to explore and expand their own understanding? (26/10)

That tension was only too evident on my next visit to the school (30/10), as I watched Tony give the only lesson he had been assigned in which he could vaguely entertain a link with the issues he had been considering. It was a public speaking lesson in which the children could generate their own two-minute speeches.

In his presentation to his tertiary advisor on his return to campus, Tony echoed Prue's feelings about the collegiality that they had developed at the school, both within their group of students and as a microcosm of a school in which there was "a whole school culture of professionalism and excellence." He felt that he had experienced a "breakthrough in his understanding of constructivism," an idea first introduced to them through Science and Technology Education subjects. However, he argued that the structure of his practice teaching classroom did not make this learning easy for him. Whilst his teacher continually expected him to quicken the pace of discussions, he wasn't doing that. He wanted to take the time to find out what the children valued, noting, "That's what constructivism and the GVC helped me to focus on. The teacher worked in a much more structured style and that didn't help me. There was a 'guess what's in my head approach to teaching' ... [and] a danger of falling into approaches I don't admire."

Just like Prue, Tony had developed a personal agenda over the three weeks of his practicum. However, Tony's revolved around valuing and his sense that it was central to the educational process. He was setting out to understand it and to develop a practice that expressed it, and he was mustering all the resources available to him to do so. He was drawing on his own experience of being valued in the hybrid e-learning system in which he found himself a significant part. He was pursuing the origins of children's valuing in the real and virtual classrooms; and he was scrutinising models of teaching practice (both his own and those he saw) for the degree of emphasis they appeared to place on children's values. Unfortunately and frustratingly for Tony, his classroom teacher's teaching model did not survive his scrutiny. Worse still, it constrained his ability to explore strategies that might support his desired approach in his own classroom practice. Nevertheless, it was encouraging to hear that on the last day of the practicum Tony had been able to observe a teacher whose teaching model appeared to him to express those principles he intended to develop in his own professional practice. This opportunity seemed to offer him a real and satisfying object-to-think-with (after Papert, 1980).

Situating these two stories: Some insights into other students' stories

Prue's and Tony's stories were only two of five that could have been told here.

- Clive's initial interest focused on the powerful benefits, for him, of being able to sit back in his own time and space, and look at what the children in the Generative Virtual Classroom did. Furthermore, that experience appeared to highlight, for him, the ways that children brought their prior knowledge to bear on making sense of their world. This strong impression is reflected in his contributions to the email discussion and to the community database. The earliest implication Clive drew from this was the urgency of "getting it right" as a teacher: in his view, the children would draw on what you told them and therefore your information needed to be correct. At the same time, Clive strongly expressed his own uncertainty specifically about the meaning of the word generative and more generally about the purpose of the e-learning environment; and he returned to this worry in several ways over the course of the three weeks. In an early conversation, for example, he was trying to identify characteristics of a generative approach by questioning whether and if so how one could take a generative approach in other key learning areas, Personal Development, Health and Physical Education. "I would love to know what it is so that I can efficiently do it." From this consideration and by thinking aloud about what he was seeing the children do in the GVC, a critical feature of it for him was what he called problem-solving, although he did not explicitly pick up the fact that the children in the GVC were setting their own problems. In the first lesson he chose to teach for me (in which children tried to figure out why it is so cold in Antarctica), he told me, "I did my level best to emulate the style of what I saw in the GVC," but he explicitly conceived of the possibility that he had misinterpreted the generative approach (disappointed though he would have been if that had been the case). In essence, he was casting his lessons as a test of the generative approach for him: not only to see what happened and give him a real-world view of how children made sense of their world, but also to try to imitate what he had seen in the Generative Virtual Classroom. He contrasted these perspectives with the way he learned Science Education on campus, by doing activities themselves and hearing about, but not seeing, ways one might implement such activities in classrooms.
- As the only student at School 2, and so without an on-site learning community, Tina made many more written contributions to the GVC itself through both the community database and the email discussion list than any other student in the study. As a Science graduate herself, she seemed comfortable with the

language of the GVC: she could talk quite easily about generating and testing ideas. The essence of her story was her use of the GVC to alert her to the connections (which she could then see in her own classroom) between her own science and the way young learners might learn science. Of particular significance in Tina's story was her view that she had not made such connections as much previously in Science Education classes at University. In her view, this was because the particular topics had not figured in her University science courses and because "we aren't watching kids [do science]. It was different. We were doing it ourselves, so I wasn't making those connections as much, probably." Now, for example, Tina could discern the value of continuing to seek children's explanations for a phenomenon long past when a child contributed the scientifically accepted view, to enable a rich set of possible explanations to be considered. She could explore the worth of thinking philosophically about how satisfying or complete a scientific explanation (of magnetism in terms of the alignment of domains) might be for her and for the children; and, prompted by what she saw in the GVC, she could draw up a list of science topics which might be of value for young learners and discuss cogently how they differed from the list she might have drawn up prior to this experience.

- Jill's personal and professional circumstances exerted powerful influences on her learning over the three-week practicum. At the very first assembly at the school, she made eye contact with a little boy with cerebral palsy in the hall and decided, then and there, that she would like to do her practicum on that Year 1 class. As it happened, there was a host of factors surrounding the functioning of that class which monopolised her attention and with which she dealt, diplomatically and competently, over the practicum period. Consequently, it did not prove possible for Jill to have much control at all over the planning of her teaching. As well, simultaneously, she had to cope with the serious illness, hospitalisation and major surgery of her partner. In these circumstances, though she contributed written comment to the GVC community database and to the email discussion, she expressed in her report to her tertiary advisor that she "could not put [these ideas] into practice in the classroom in that context. My main reflection was [about] myself as a learner, rather than myself as a teacher." In this sense, her story is similar to those of others who have worked in the Generative Virtual Classroom outside a school setting (for example, Allard, 1998). Interestingly, though, it differed from Allard's in that whilst Allard worked alone with a previous version that was not being used over a network at the time, Jill admitted that she "used the discussion with others if I didn't understand something. I could learn from others by listening to the GVC as I would as a learner [in a real classroom]."

Furthermore, once gathered back at University nine days after the practicum ended, the experience took on yet another character in the group's discussion of it. The students wanted to know how the e-learning environment had originated; they wanted to know its developmental history; and they wanted me to tell them my purposes for it. Though I complied with their first two requests, I turned the last question back to them to answer. They could see a wealth of applications for it, including:

- A professional development resource for experienced teachers in schools;
- A part of an initial teacher education program for students to use anywhere, anytime;
- A general-purpose architecture to use in any educational setting where a teacher might want to blend video with discussion in a simple computer-mediated environment.

They identified many of its salient design features, such as:

- The deliberate incorporation of community, so learners feel supported by and a vital part of something much bigger than themselves;
- The calculated use of a real (not contrived) archive of exemplary practice that one might never see by visiting schools or on practice teaching;
- The opportunity for critique and discussion of different approaches, so as to generate and test ideas about them; and
- The use of a technological medium by which teachers can learn, incidentally addressing their reportedly low levels of confidence in such contexts.

Predictably, from their short experience, these students did not discuss the use of this e-learning environment to track the development of ideas over time. Nor, given their experience in a group of students they knew and with whom they felt comfortable, did they raise ideas about remote learners or larger numbers of learners, unknown to each other, for whom such an environment might prove more accessible than a University campus located in time and space. However, they seemed to be convinced of the advantages of being able to tap into a whole community's thinking via a shared experience of learning events, a database and an email discussion.

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As the conversation progressed, there were even deeper insights into the environment and its possible worth. One student suggested that the environment itself could function as a measure of teachers' values and attitudes, and added, somewhat sinisterly, "for an outside party." Another student, who worked as a courier at night, envisaged the dilemma of being asked to reflect on this work. "How would I do it? What would I want to look at? I do critical reflections all the time at Uni but how would I do it if you put me in [this] different scenario?" This student saw the GVC as a tool for undertaking (even learning how to undertake) critical reflection about teaching and learning. In essence, as I told the students, these comments expressed, as accurately as I thought was possible, the fundamental purposes for which I designed the Generative Virtual Classroom.

Analysing the findings of this study

I have argued elsewhere, in respect of e-learning systems (Schaverien, 2000), that once a learning environment is designed on a set of educational principles, it constitutes, in operation, a test of those principles. So, my first task in analysing the findings of this study is to consider whether the (biologically based) generative theory of learning on which the GVC was designed can make sense of these students' learning over the course of the study. Having considered the worth of making sense of these students' learning in biological terms, I can summarise, descriptively and analytically, the findings of the three studies reported here and consider their educational and scientific implications.

The findings of this study indicate that particular *value* positions drove and shaped the unique professional agendas of each of the five teacher education students over the course of this study. Though broadly, this learning community was driven by a common underlying value (of developing their professional capability), there were diverse ways in which students expressed this fundamental value. Subtle and, to a large extent unknown, previous life experiences may have formed these values and they influenced and were influenced by the real time events and experiences of the study itself. For example, Prue came in to the study with feelings of competence about teaching generally but with particular hesitation about and a sense of wanting to improve her understanding of science and science learning. Clive was impressed with the e-learning environment itself and with what he could see of the children's learning there, but uncertain as to what a generative teaching approach meant; he seemed to want to understand it by trying out for himself what he thought it was in his own classroom teaching. Each student already had, or was forming consciously or subconsciously, convictions about what they wanted to do during the study and how they wanted to do it. These convictions helped to evolve some personal agendas and cull some others: as a result of them, students were differentially attuned to salient facets of their experience. For example, in one of our conversations and quite understandably in the circumstances, Prue took my word "strategies" to mean teaching strategies rather than learning strategies as I had meant it. The strength of Jill's professional agenda and the challenging circumstances that confronted her led her to make what she saw as the only possible decision: to limit her engagement with the GVC to understanding her personal learning rather than her teaching. These learners' values occupied a central place in their learning.

The study documents many examples of the ways students *generated and tested ideas* (their own and others'), *on their value for them*, over the course of these three weeks. This generating and testing was clearest in this study when it happened minute by minute or over days, for example, in the detailed reports of conversations with Prue and Tony and the relationships between these comments, these students' written contributions to the GVC and teaching and learning events occurring in their classrooms. Major shifts in students' ideas are less clear from the data. I speculate that there are several reasons for this. First, the study was necessarily of very short duration, fitting as it did into a routine practicum, and even further curtailed due to technical difficulties beyond my own, the students' and the schools' control. This provokes thinking about the length of time needed for such intellectual work to occur, the appropriate time-span for practice teaching experiences and the need for a follow-up investigation of these students' thinking some months hence. Certainly, both the second study reported here (Allard, 1998) and a previous study of learning to teach in a school-based but not computer-mediated learning environment (Schaverien and Cosgrove, 1997a) have demonstrated the need for much more sustained periods of time if deep thinking is to occur. Secondly, there were significant constraints on my time as a researcher during this period, with other continuing teaching responsibilities, constraints on the times students could teach classroom lessons or participate in conversation and constraints due to the particular circumstances and tensions in classrooms. Such difficulties certainly affected the findings, for it was not always possible for students to teach the sorts of lessons they most wished to teach to illuminate their thinking. These constraints provoke thinking about how opportunities for students to learn during practice teaching in ways that support their generating and testing of ideas might be enhanced. Nevertheless, to the extent that this was possible in such a

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short study, these findings provide evidence that this learning can fruitfully be understood as learners' generating and testing ideas on their value.

The findings of this study illustrate the *diversity of learning pathways possible* for students in a complex, hybrid e-learning system and the multitude of influences, prior and in real time, that pertain. For example, the inclusion of the GVC for students at School 1, together with the schedule they worked out for devoting time to it, resulted in the opportunistic provision of half an hour of time which these students deliberately exploited for collaborative conversation. The positive consequences of this serendipity might suggest the worth of providing such space for all students during practicum, although factors unique to these students in these circumstances may well have been responsible for its success. A second student who had been placed at School 2 withdrew without notice at the beginning of the practicum period. Tina appeared to use her participation in the GVC experience to compensate her for the lack of a student community on-site; and, though this cannot be affirmed conclusively, it is likely that her personal and professional insights increased as a result.

As well as those influences reported here, there were others of which I am aware but have not included in this account. For example, several students placed at School 1 mentioned, in their presentations to their tertiary advisor, the strong influence on their thinking of their school principal. One student attributed this to his extraordinarily generous commitment of time and effort to them as students. Several students stated that though they had at first found his forthright perspective confronting and challenging, he had, in the words of one, "given them a perspective they didn't have." It is highly probable that this principal's contribution influenced the successful growth of these students' collegial group, both directly and indirectly through the culture of his school. Of course, there must have been other events and circumstances, influencing students' learning over the course of this study, to which I was not even privy.

On these grounds, to the extent that this is possible in such a short investigation, a biologically based generative theory of learning appears to make powerful sense of the learning of these students in this study. In fact, their learning appears to have much in common with the human development Thelen and Smith (1994) have investigated and described in these terms,

> Although behavior and development appear structured, there are no structures. Although behavior and development appear rule-driven, there are no rules. There is complexity. There is multiple, parallel, and continuously dynamic interplay of perception and action, and a system that, by its thermodynamic nature, seeks certain stable solutions. These solutions emerge from relations, not from design. When the elements of such complex systems cooperate, they give rise to behavior with a unitary character, and thus to the illusion of structure. But the order is always executory, rather than rule-driven, allowing for the enormous sensitivity and flexibility of behavior to organize and regroup around task and context. (p. xix)

That is, Thelen and Smith (1994) are arguing that development is complex, context-specific and emergent, rather than being simple, automatically generalisable over different contexts and pre-ordained. What needs to be explained, in their view, is not stability but novelty and change. To this end, they have proposed treating human development as the behaviour of a non-linear, self-organising, dynamic system, a view which is consistent with the value-driven, biologically based, generative theory of learning in terms of which the findings of this study have been explained.

Summary and implications of these three studies

These three studies indicate that the GVC can provoke learners' deep, imaginative and critical exploration of ideas about learning. In all three studies, students evidenced and reported gains in their ability to describe learning and to formulate criteria by which they might recognise it if it occurred. Even more significantly, there is evidence that some learners, not only in the more sustained studies but also in the three-week-long third study, were beginning to relinquish instructionist views of learning (as occurring only by being told); and many students could clearly articulate both what they felt they now knew about learning and what they considered they still needed to know.

The findings of all three studies affirm the significance of taking characteristically biological approaches to educational research in at least the three ways foreshadowed in the introduction to this paper. For most students, learning as part of a learning culture was central: even Megan, perhaps the most isolated of these learners, sought out other learners (her daughter, her peers, other teachers). A biological perspective on learning

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appeared to supply learners with appropriate language to describe and analyse learning, both their own and others'. The ways that learners talked about learning appeared to indicate that they held a view of learning as a knowledge frontier rather than as settled knowledge, able to be transmitted. This was particularly the case in the first and second studies where students were able to engage with ideas about learning over a longer period of time.

These studies extend the body of evidence, both within and outside education, affirming the worth of adopting biological perspectives in learning research. For Sacks (1995), a biologically based learning theory made sense of hitherto unexplained neuropsychological effects, for example, the failure of one of his patients (a man blind almost from birth) to see immediately, once his cataracts had been removed. For Thelen and others (1993), it explained the idiosyncratic nature of infants' development of psychomotor competence, in particular in their reaching for and grasping a toy. As has been noted already, in describing the antecedents of the view of learning adopted here, evolutionary epistemologists (Plotkin, 1994, 1997), evolutionary and biological psychologists (Cosmides and Tooby, 1992) and some biologists (Edelman, 1993) are converging on a unified understanding of knowledge and knowledge-gaining, at the nested levels of genes, individuals and cultures. Such insights recognise the worth of viewing learning as a generative act (after Minsky, 1985, and Wittrock, 1974, 1994). As well, they draw on key concepts and methods from the philosophy of biology, for example,

- by expecting a plurality of causes for and reciprocal influences on behaviour,
- by accepting levels of complexity or complex hierarchies,
- by dealing in probabilistic (rather than prescriptive) theories,
- by acknowledging the existence of dynamic, self-organising systems (in particular, living ones),
- by anticipating chance and variation (in particular, in populations of unique individuals) and
- by introducing historicity into science (Mayr, 1982, 2000).

These advances are shedding further philosophical light on the existence of consistent sets of explanations for complex biological phenomena (Churchland, 1995; Dennett, 1998) (conceivably including learning) and on the processes themselves (for example, development) which are being explained (Griffiths and Stotz, in press; Thelen and Smith, 1994); and they are generating new explanations for cultural and social phenomena (Boyd and Richerson, 2000; Buchanan, 2000; Singer, 1999). After a long history of separation between Education and the biological sciences, these are signs that the gulf is diminishing.

The GVC's solution to the problem of nurturing larger numbers of prospective elementary school teachers' development of sophisticated, cutting-edge ideas about learning provides an innovative model of the use of advanced technologies for learning in education and in particular, in teacher education; and it does so both strategically and conceptually. It attempts to exploit the educational power of new media as fully as is currently possible. For example, it uses:

- the power of a digitised video archive to create an authentic classroom learning context for student teachers who may be geographically distant from real children learning technology-and-science (in a similar way to the clinical archive at the Iowa Medical School's Virtual Hospital (http://www.vh.org/));
- the power of the internet to connect learners, dispersed in time and space, through common experience of events in a virtual elementary classroom and through reactions to events and to others' interpretations of them (in ways which draw on insights from Goldman-Segall's (1991) pioneering video-ethnographic research tool, Learning Constellations, and electronically-mediated forms of learning, such as the Continuing Medical Education Club at the Goodfellow Unit, Department of General Practice, Faculty of Medicine and Health Science, University of Auckland (http://cmeclub.auckland.ac.nz/)); and
- the opportunity afforded by a self-managed, computer-mediated learning environment to pursue diverse paths through a range of activities in a self-determined sequence and at an idiosyncratic pace (similarly to others in this family of learning environments, for example, Cosgrove and Alexander's (1995) Views of Electricity).

If the GVC is successful in providing a context for larger numbers of teacher education students to learn subtle new ideas about learning in ways which respect and accommodate individuality, as these studies indicate, then important new directions in teacher education will have been forged. Primary emphasis will have been placed on the importance of developing student teachers' fascination with learning, as a prerequisite for contemplating how to nurture learning through teaching. Such an approach recasts teachers as researchers, mining classrooms for evidence of learning and refining practice by monitoring such evidence to try to enhance learning. Such an approach to professional formation is in tune with recent developments in other disciplines, particularly those

that have a vested interest in successful, research-based innovation (for example, see Godlee (1998) on evidence-based research reports in medicine).

At least as significant as these educational implications of the GVC are the scientific ones, for they bring purpose to the educational enterprise. The GVC appears, from initial studies, to have the potential to engage educators directly with current scientific and philosophical debates about brains, minds and consciousness. Educational evidence arguably provides a crucial test-bed for such views but mainstream educational theorising has remained curiously isolated from these discussions in the culture. Of course, Papert (1980) and Minsky (1985) made pioneering educational contributions to this debate; and Wilensky and Resnick (1999) continue to do so with respect to artificial life and dynamic and complex systems. Given the cultural prominence of such ideas as contemporary materialist philosophers' views of brains and minds, the time appears ripe for educators to examine them and to enrich debate, in turn, with research findings from education. The design of the GVC and the analysis of the learning system of which it is a part offer insights into how educators might contribute, through teacher education, to the spread of current but still rare insights into learning in the culture, with consequent promise of improvement in the profoundness and the subtlety of educational provision.

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